

Rejection of Claims 1, 2, and 5 under 35 U.S.C. §103 over Satou et al in view of Ovshinsky

Claims 1, 2, and 5 were rejected under 35 U.S.C. §103 as obvious over Satou et al (U.S. Patent No. 5,961,850) in view of Ovshinsky et al (U.S. Patent No. 5,324,553). The Examiner takes the position that Satou et al teaches various limitations of the claimed invention, as listed in items i. through viii. on pages 2 - 3 of the Office Action. The Examiner acknowledges that Satou et al does not teach (ix.) a gas that contains at least carbon and fluorine wherein a gas species is generated which contains carbon and fluorine according to a plasma dissociation, and (x.) plasma generation means which generates a plasma in which the degree of plasma dissociation is a "middle" degree and the gas species containing carbon and fluorine is generated fully in the plasma. The Examiner alleges that Ovshinsky teaches a similar plasma ECR processing apparatus, a microwave frequency in the 300 MHZ to 1 GHz range, a plasma generation means in which the degree of plasma dissociation is a "middle" degree and average electron energies around 2 eV. The Examiner alleges that because Ovshinsky discusses average electron energies, it would be expected that electron energy values less than the average would be expected to fall within the range of 0.25 eV to 1 eV. The Examiner takes the position that it would be obvious to implement Ovshinsky's microfrequency range and plasma middle degree of dissociation as operating conditions for Satou's plasma ECR processing apparatus. The Examiner alleges that motivation for implementing Ovshinsky's microfrequency range and plasma middle degree of dissociation as operating conditions for Satou's plasma ECR processing apparatus is drawn from Ovshinsky's benefit of resonating different atomic components present in the plasma including higher energy transfers to neutrals resulting from a larger ratio of resonating ions.

This rejection is respectfully traversed. The present invention is directed to a plasma processing apparatus for etching and method for plasma processing using a gas containing gas species that contain fluorine and carbon. Features that distinguish the present invention from the methods described in the cited references include that the degree of plasma dissociation is a middle or intermediate degree (that is, a relatively high level of CF₂, and CF compared to the amount of F). As explained more fully in the specification, for example, on pages 2 - 3, a middle or intermediate degree of dissociation is desirable for etching silicon oxide. As stated previously, these features are neither disclosed nor suggested by the cited references. In particular, Satou et al does not disclose processing with gas species containing carbon and fluorine. There is no teaching or suggestion in Satou et al of an apparatus for controlling the extent of dissociation of a processing gas or for using a plasma excitation frequency of 300 MHz to 1 GHz.

Moreover, Ovshinsky does not supply the elements missing from Satou et al. Ovshinsky relates to a method for the improved microwave deposition of thin films. That is, the invention described in the reference does not relate to a plasma etching apparatus as in the present invention but rather, relates to methods and apparatus for plasma deposition of film (for example, CVD). Plasma etching is completely different from plasma deposition of film, since etching removes thin films, whereas film deposition grows deposits on a wafer. Accordingly, the apparatus constitution, the method of using the apparatus and the process conditions are naturally different from each other, and teachings in one art do not translate to the other art. Accordingly, Ovshinsky is not properly combinable with Satoh.

Further, the Examiner is in error in asserting that Ovshinsky teaches the frequency of microwaves in the range of 300 MHz to 1 GHz in any process or apparatus

relevant to the present invention. The mention in the reference of 915 MHz is only with respect to use in PECVD (Plasma Enhanced Chemical Vapor Deposition) and not in an etching method or apparatus.

Moreover, the Examiner is in error in alleging that Ovshinsky describes that dissociation is at an intermediate degree. Ovshinsky merely describes that the average energy of electrons is 2 eV, they constitute a Maxwell-Boltzmann distribution and the degree of ionization is extremely low at a pressure of 0.5 - 1.0 Torr. Dissociation and ionization are different. While dissociation includes various processes, the term refers to the process by which electrons under ECR acceleration by microwaves waves collide against molecules to decompose them (for example CF_4 is decomposed into F and CF_3), in which the energy is determined on every dissociation reaction and does not change depending on the pressure. Further, in a plasma at an average electron energy of 2 eV, there is the problem that the dissociation proceeds excessively (for example, CF_4 is decomposed into CF or F, and the amount of CF_2 or CF_3 is decreased). Therefore, it is important to have a lower average electron energy in an etching apparatus and method. The mere presence of electrons at 0.25 - 1 eV is not effective if the average electron energy of the plasma is 2eV. Further, the electron energy is that accepted by electrons when they are accelerated at a frequency of ECR, which corresponds to the frequency of microwaves.

The Examiner alleges that Ovshinsky describes the dissociation at an intermediate degree in column 10, lines 3 - 6 and column 10, lines 35 - 65. However, this passage merely describes that the feature of microwave ECR resides in the high degree of ionization. Dissociation is not mentioned.

While the Examiner alleges that Ovshinsky also discusses ionization, it must be understood that the ionization and the dissociation are different. Dissociation proceeds

in the presence of electrons at high energy, whereas ionization proceeds when the density of electrons is high (electron having energy higher than the ionization energy: which is lower than the dissociation energy). If the density of electrons at high energy is higher, both the dissociation and ionization proceed naturally. However, what Ovshinsky describes is that ionization proceeds because the electron density is high in ECR (this has a same meaning as high plasma density, which is described in column 10, line 60)

The Examiner also mentions the cyclotron resonance of ions but the present invention does not utilize the cyclotron resonance of ions. What accelerates the ions is a high frequency bias applied to a wafer boat, and cyclotron resonance is not utilized.

Accordingly, Ovshinsky does not provide relevant teachings or suggestions for modifying the apparatus and method of Satou to meet the limitations of the present invention.

Accordingly, Claims 1, 2, and 5 would not have been obvious over Satou et al or Ovshinsky, alone or in combination.

Rejection of Claims 4, 6, 7, 9 and 10 under 35 U.S.C. §103 over Satou et al and Ovshinsky and further in view of Akahori

Claims 4, 6, 7, 9 and 10 are rejected under 35 U.S.C. §103(a) as obvious over Satou et al (U.S. Patent No. 5,961,850) in view of Ovshinsky (U.S. Patent No. 5,324,553) and further in view of Akahori et al (U.S. Patent No. 6,215,087). Satou and Ovshinsky are applied as discussed above, and Akahori is applied as allegedly teaching intermittent microwave application. The Examiner takes the position that it would have been obvious for Satou or Ovshinsky to implement the Akahori intermittent microwave application.

This rejection is respectfully traversed. The differences between the present invention and the teachings of Satou and Ovshinsky are as discussed above. As with Ovshinsky, Akahori relates to plasma film forming methods and apparatus and not to etching methods and apparatus for etching with a carbon and fluorine-containing gas. (Although the reference mentions etching, this is in connection with O₂ gas used to round out shoulders as part of an embedding process.) In particular, film forming on a wafer involves deposition of particles of large deposition probability or particles for film deposition, and such particles must be suppressed in etching, since they interfere with the etching process. Accordingly, the teachings of Akahori are not relevant to the present invention. For example, the teachings of Akahori of modulating microwaves into pulse-like form (pulsed microwaves) is for the purpose of increasing electron temperature, thereby increasing radicals at high energy and increasing deposition speed, whereas in the present invention, in the context of etching, the use of intermittent microwaves is to control dissociation and improve etching performance by lowering the electron temperature.

Accordingly, Claims 4, 6, 7, 9 and 10 would not have been obvious over Satou, Ovshinsky, or Akahori, alone or in combination.

Conclusion

In view of the foregoing amendments and remarks, it is respectfully submitted that Claims 1, 2, 4, 5, 6, 7, 9 and 10 are in condition for allowance. Favorable reconsideration is respectfully requested.

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Respectfully submitted,

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